Lagrangian Data Analysis in Mesoscale Prediction and Model Validation Studies

Annalisa Griffa, Tamay Ozgokmen
Meteorology and Physical Oceanography Department
Rosenstiel School of Marine and Atmospheric Science
4600 Rickenbacker Causeway, Miami, Florida 33149
phone: (305) 361 4892, fax: (305) 361 4696, email: anna@mamey.rsmas.miami.edu
Award #: N000149710620

LONG-TERM GOALS

The long term goals of this proposal are the development and application of new methods of investigation for the use of Lagrangian data. Special attention is given to the combined use of data and models, in terms of model validation and statistical prediction.

OBJECTIVES

The specific scientific objectives of the work done can be summarized as follows:

1) Investigation and statistical prediction of mesoscale transport properties using Lagrangian data analysis in conjunction with stochastical models. Two applications have been completed, one in the Equatorial Pacific Ocean, and the other in the Adriatic Sea (a sub-basin of the Mediterranean Sea).

2) Investigation of problems of model-data intercomparison using Lagrangian data, with special interest on error analysis. Applications are performed using models at different scales: i) a regional model of the Sicily Channel (Mediterranean Sea), and ii) a basin-scale model of the Atlantic Ocean.

APPROACH

The work is based on a probabilistic approach. It involves a combination of analytical, numerical and data processing techniques.

WORK COMPLETED

A study started in the previous years of the grant has been computed, dealing with transport estimates in the Equatorial Pacific Ocean. This study is part of the thesis dissertation of S. Bauer, the student supported by this grant in the period 1997-1998, who has now graduated. Results of her research are contained in her dissertation thesis, and in two papers, one printed and the other to be submitted.

A study on mesoscale transport in the Adriatic Sea has been completed, analyzing a Lagrangian drifter data set. The results are contained in two submitted papers.

A study of intercomparison between model results and Lagrangian data has been completed in the Atlantic Ocean, while preliminary results have been obtained in the Sicily Channel. The results are described in two submitted papers.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1999**	2. REPORT TYPE	3. DATES COVERED **00-00-1999 to 00-00-1999**

4. TITLE AND SUBTITLE **Lagrangian Data Analysis in Mesoscale Prediction and Model Validation Studies**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Miami,Rosenstiel School of Marine and Atmospheric Science,4600 Rickenbacker Causeway,Miami,FL,33149**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

RESULTS

The main results, obtained in collaboration with other scientists, in particular with P.-M. Poulain (NPS, Monterey), with whom we have shared data and analysis, can be summarized as follows:

1) A study of surface transport in the Equatorial Pacific Ocean has been completed, including the estimation of time/space varying diffusivities from historical Lagrangian data and their application to heat flux calculations. Emphasis is on the resolution of inhomogeneity and nonstationarity of the flows, in order to correctly evaluate diffusivities. Impacts of waves and coherent structures on the evaluation are considered, and new methodologies of analysis are developed. The work has been performed in collaboration with the student S. Bauer supported by this grant, A. Mariano (RSMAS) and M. Swenson (NOAA).

2) The surface transport in the Adriatic Sea has been studied considering a drifter data set (1994-1996). Three main points have been addressed. First, the role of topography in transport properties has been studied. A significant cross-topography exchange has been found, probably due to stratification and direct wind forcing. Second, a stochastic Lagrangian model of transport has been implemented, and tested with positive results against data results (Fig.1). Finally, the residence time, i.e. the average time spent by a surface particle in the basin, has been estimated using data and model results, suggesting a residence time of approximately 200 days. The predictability properties of the Adriatic Sea has been also studied (Castellari *et al*., 1999), as illustrated in detail in the annual report of Grant N00014-99-1-0049. These results have been obtained in collaboration with S. Castellari, the RSMAS post-doctoral fellow supported by this grant in 1998-1999, P.-M. Poulain (NPS) and E. Zambianchi (University of Naples, Italy).

3) A circulation model of the Sicily Channel has been implemented. In the next year of the grant, the model will be validated using surface drifters data and it will be used in a study of mesoscale transport processes. Upwelling phenomena and coastal/deep ocean exchanges will be considered. The model (OPA model, Herbaut et al., 1996) is primarily density driven (even though local wind forcing will also be considered). Fresh Modified Atlantic Water (MAW) flows eastward in the surface layer, while saltier Levantine Intermediate Water (LIW) flows westward at a depth around 300m. Comparison with historical hydrographical data show that the model correctly reproduces the main path of the LIW and describes reasonably well the MAW (Molcard et al., 1999). Implementations in the forcing (local winds) and in the buffer zones are expected to further improve the model performance in the upper layer. Preliminary calculations of "typical" numerical drifter trajectories have been performed, considering the annual average velocity, whose main patterns appear to be semi-stationary, i.e. recurrent also in most snapshots (Fig. 2a-b). From a first qualitative comparison with in situ drifter trajectories (*http://www.oc.nps.navy.mil/~poulain*), the numerical trajectories appear to capture many of the characteristics of the Lagrangian flow. These results have been obtained in collaboration with A. Molcard (CNR, La Spezia, Italy), who is presently starting as RSMAS post-doctoral fellow supported by this grant, L. Gervasio and L. Mortier (LODYC, Paris, France), G. Gasparini (CNR, La Spezia, Italy).

4) A model-data intercomparison has been carried out in the Atlantic Ocean, using historical in situ surface drifters, considering and studying new methodologies. This study has been supported also by the NSF grant OCE 9811358. The comparison is performed using Lagrangian data simulated in a high resolution MICOM run (Paiva et al., 1998). Pseudo-Eulerian statistics such as mean velocity and eddy kinetic energy have been compared, as well as Lagrangian statistics such as integral time scales. The different characteristics of the space/time distributions of the 2 data sets (model and n situ drifters) are

considered, as well as the statistical errors, at least for the pseudo-Eulerian quantities. A statistical test (James test) is performed to assess the significance of the differences in the mean flow estimates. The comparison indicates an overall satisfactory agreement between data and model, even though some significant difference persists. The most relevant one is that the model appears to be less energetic than the data in the interior, probably due to the lack of high frequency winds in the model forcing, causing an underestimate of the directly forced eddy variability. The comparison suggests possible model improvements, in terms of forcing, buffer zones and implementations. The MICOM Lagrangian simulations have also been used to study the errors in the estimates of mean flow and the effects of sampling. The results suggest that drifters tend to sample preferentially the high energy frontal regions of eddies and jets, resulting in a bias in the mean flow estimates with respect to the purely Eulerian estimates. This work has been done in collaboration with E. Chassignet, A. Mariano, Z. Garraffo (RSMAS).

IMPACT/APPLICATIONS

The results have the potential to impact current studies for a number of problems. From the point of view of statistical prediction of transport, i.e. identification of "probability density maps" for particle positions, the results show that, at least for surface flows, it can be performed using appropriate stochastic models parameterizing particle motion. Predictions appear appropriate even in presence of strong inhomogeneities, such as in Equatorial sheared flows and in coastal and boundary areas.

The use of Lagrangian data to validate numerical models appear very promising, since they tend to have good coverage of extensive regions. Understanding their statistical errors is crucial to a correct quantitative intercomparison.

TRANSITIONS

Lagrangian stochastic models for the statistical prediction of transport are planned to be used in the analysis of a drifter data set in the Caribbean Sea, in collaboration with K. Leaman (RSMAS).

Intercomparison methods for model and Lagrangian data results are planned to be used in transport studies in the Western Mediterranean Sea, in collaboration with P.Poulain and E. Zambianchi.

RELATED PROJECTS

Related projects are carried out with other investigators funded by ONR, NSF, NOAA and the European Science Foundation (TAO Project).

Applications of the new analysis method to Lagrangian data sets and model intercomparison are carried out with M. Swenson (NOAA), A. Mariano , E. Chassignet and Z. Garraffo.

Particle cluster studies and the relationship between Eulerian and Lagrangian models is performed in collaboration with L. Piterbarg (USC), E. Zambianchi and G. Buffoni (ENEA, Italy).

REFERENCES

Herbaut C, L. Mortier, M. Crepon, 1996. A sensitivity study of the general circulation of the Western Medterranean Sea. 1: the response to density forcing through the straits., J. Phys. Oceanogr., 26, 65-84.

Paiva A.M., J. T. Hargrove, E.P. Chassignet, R. Bleck, 1998. Turbulent behavior of a fine mesh (1/2 deg) numerical simulation of the North Atlantic, J. Mar. System.

PUBLICATIONS (1998-1999)

Bauer S., M. Swenson, A. Griffa, A. Mariano and K. Owens, 1998: Eddy-mean flow decomposition and eddy-diffusivity estimates in the Tropical Pacific Ocean. Part 1: Methodology. J. Geophys. Res., 103, C13, 30855-30871.

Buffoni G., A. Griffa and E. Zambianchi, 1999: Modelling of dispersion processes in a tide-forced flow. Hydrobiologia, 393, 19-24.

Falco P, A. Griffa, P.M. Poulain, E. Zambianchi, 1999: Transport properties in the Adriatic Sea as deduced from drifter data. J. Phys. Oceanogr., in press.

Castellari S., A. Griffa, T. M. Ozgokmen, P.M. Poulain, 1999: Prediction of particle trajectories in the Adriatic Sea using Lagrangian data assimilation. Submitted to J. Mar. Sys.

Garraffo Z., A. Mariano, A. Griffa, C. Veneziani and E. Chassignet, 1999: Lagrangian data in a high resolution model simulation of the North Atlantic. 1: Comparison with in-situ drifters. Submitted to J. Mar. Sys.

Garraffo Z., A. Mariano, A. Griffa and E. Chassignet, 1999: Lagrangian data in a high resolution model simulation of the North Atlantic. 2: Mean flow reconstruction and sampling effects. Submitted to J. Mar. Sys.

Bauer S., 1999: Diffusivity estimates in the Tropical Pacific Ocean. Ph.D. thesis dissertation, University of Miami.

Bauer S., M. Swenson, A. Griffa, A. Mariano, 1998: Eddy-mean flow decomposition and eddy-diffusivity estimates in the Tropical Pacific Ocean. Part 2: diffusivities and heat flux calculations. In preparation.

Molcard A., T. M. Ozgokmen, L. Gervasio, A. Griffa, and P.-M. Poulain, 1999: A numerical study of the mesoscale circulation in the Sicily Strait and comparison with surface drifters. In preparation.

Bellucci A., Buffoni G., A. Griffa and E. Zambianchi, 1998: Parametric study of dispersion processes in semi-enclosed basins. ENEAR-RT Report.

Gervasio L., A. Molcard, L. Mortier, A Griffa, 1999: A numerical study of the mesoscale circulation in the Sicily Strait. EGS Meeting.

Chassignet, E.P., Z.D. Garraffo, A. Griffa, 1999: A numerical ARGO float design study with a high resolution North Atlantic model. AGU Spring Meeting.

Garraffo, Z.D., E.P. Chassignet, A. Griffa, A. Provenzale and A. Mariano, 1999: Lagrangian statistics in a high resolution (1/12 degree) ocean. International Liege Colloquium on Ocean Hydrodynamics.

Griffa A., 1999: Transport models and Lagrangian data. International Liege Colloquium on Ocean Hydrodynamics. Invited talk.

Falco, P., A. Griffa, P.-M. Poulain, E. Zambianchi, 1998: Transport processes in the Adriatic Sea estimated from Lagrangian data, 1st National Congress of Marine Sciences, Ischia (Italy), 11-14 November 1998.

Griffa, A., P.-M. Poulain, E. Zambianchi, 1998: Estimates of Transport Parameters from Lagrangian Data in the Adriatic Sea, Oceanography of the Adriatic Sea, Trieste (Italy), 21-25 September 1998.